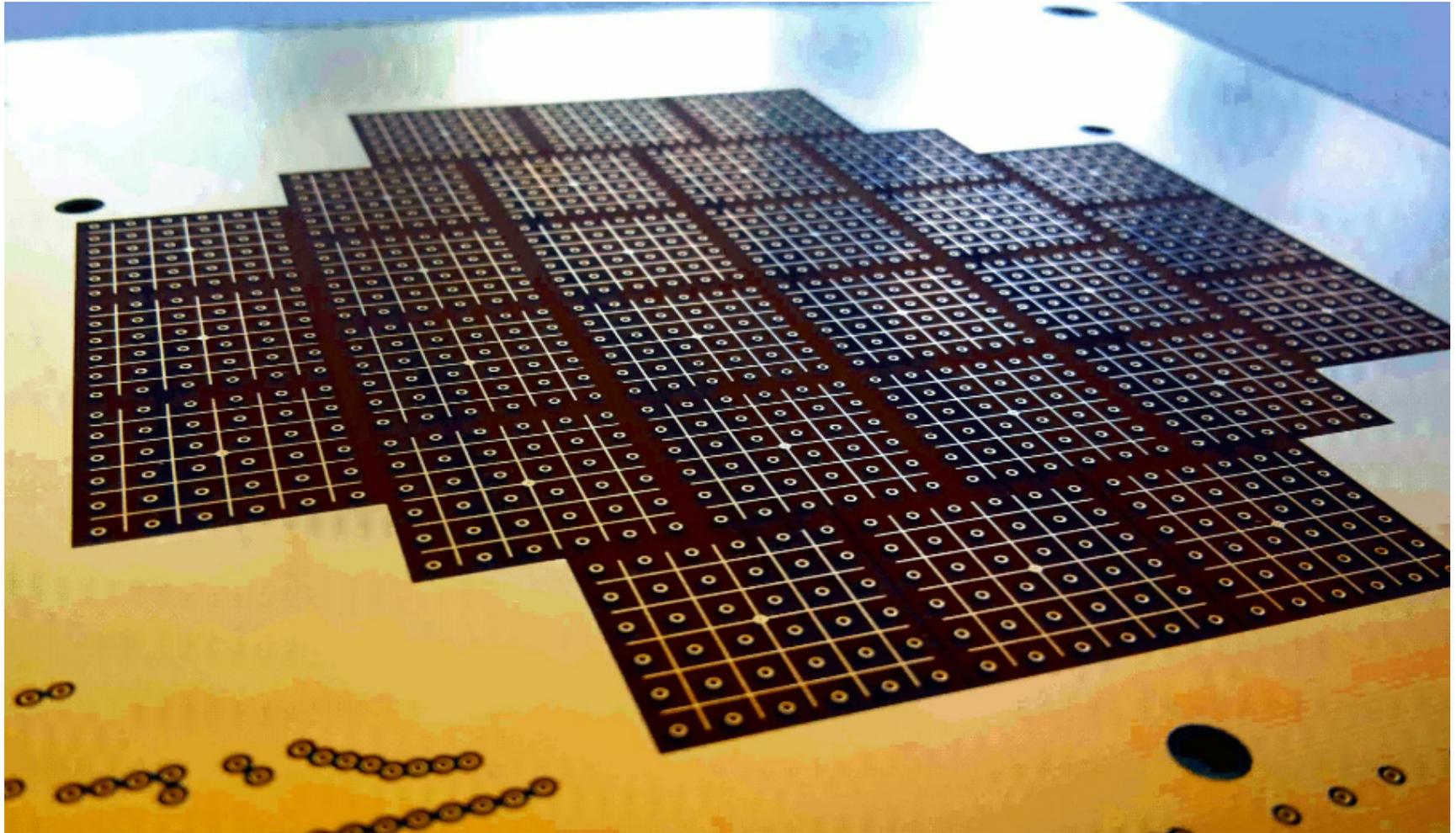


Liquid Argon Near Detector Simulation



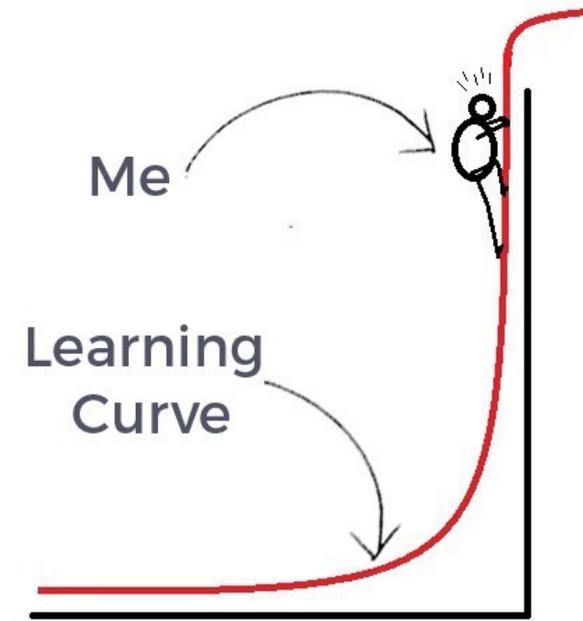
Jonathan Asaadi
University of Texas at Arlington

The Strategy

- **Near term strategy (Near Detector Task Force)**
 - Use the current tools and best understanding of particle ID and reconstruction efficiencies for a baseline of the LAr option
- **Medium term strategy (Detector Optimization)**
 - Perform a series of studies aimed at optimizing the detector configuration
 - Utilize a more lightweight tool for these
- **Long(er) term strategy (for technical design)**
 - Incorporate this optimization back into the standard simulation framework (LArSoft)

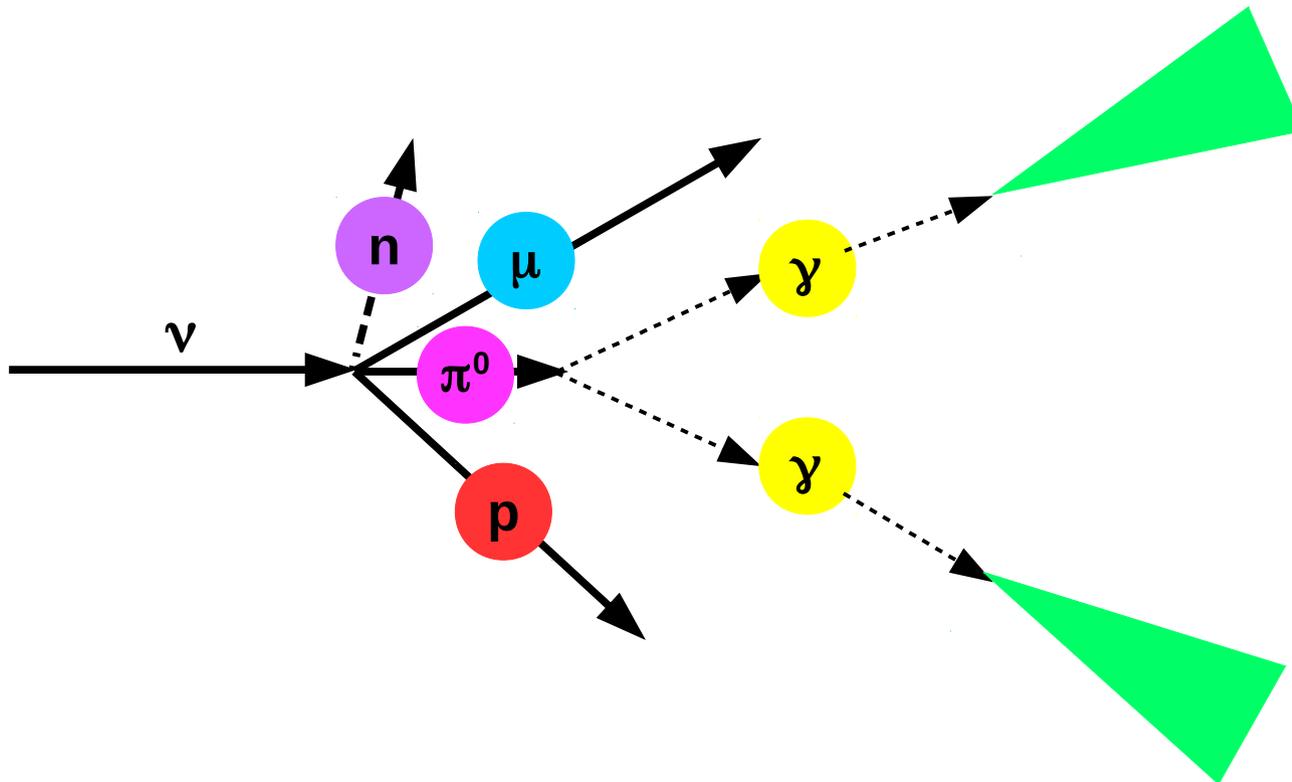
Near Term Strategy

- **We (myself and a graduate student) joined the task force in late January**
 - While we come from the liquid argon community (ArgoNeuT, LArIAT, MicroBooNE, etc...) we were unfamiliar with the tools being used in the study
 - This means that at the moment we don't have a completed study
 - But we do have a very nearly completed study that we are continuing to work on
- **Using LArSoft framework to evaluate the performance of a liquid argon near detector**
 - We encountered a few stumbling blocks along the way
 - For example LArSoft (at the moment) doesn't have pixel like charge readout simulated
 - With a deadline of March there wasn't time to even attempt to implement this
 - Our approach has been to cobble together something that would “act like” having 3-d pixel information and apply the latest and greatest reconstruction resolutions and efficiencies from the operating liquid argon experiments
 - MicroBooNE has been releasing a series of public notes on their reconstruction progress using common tools (e.g. PANDORA)



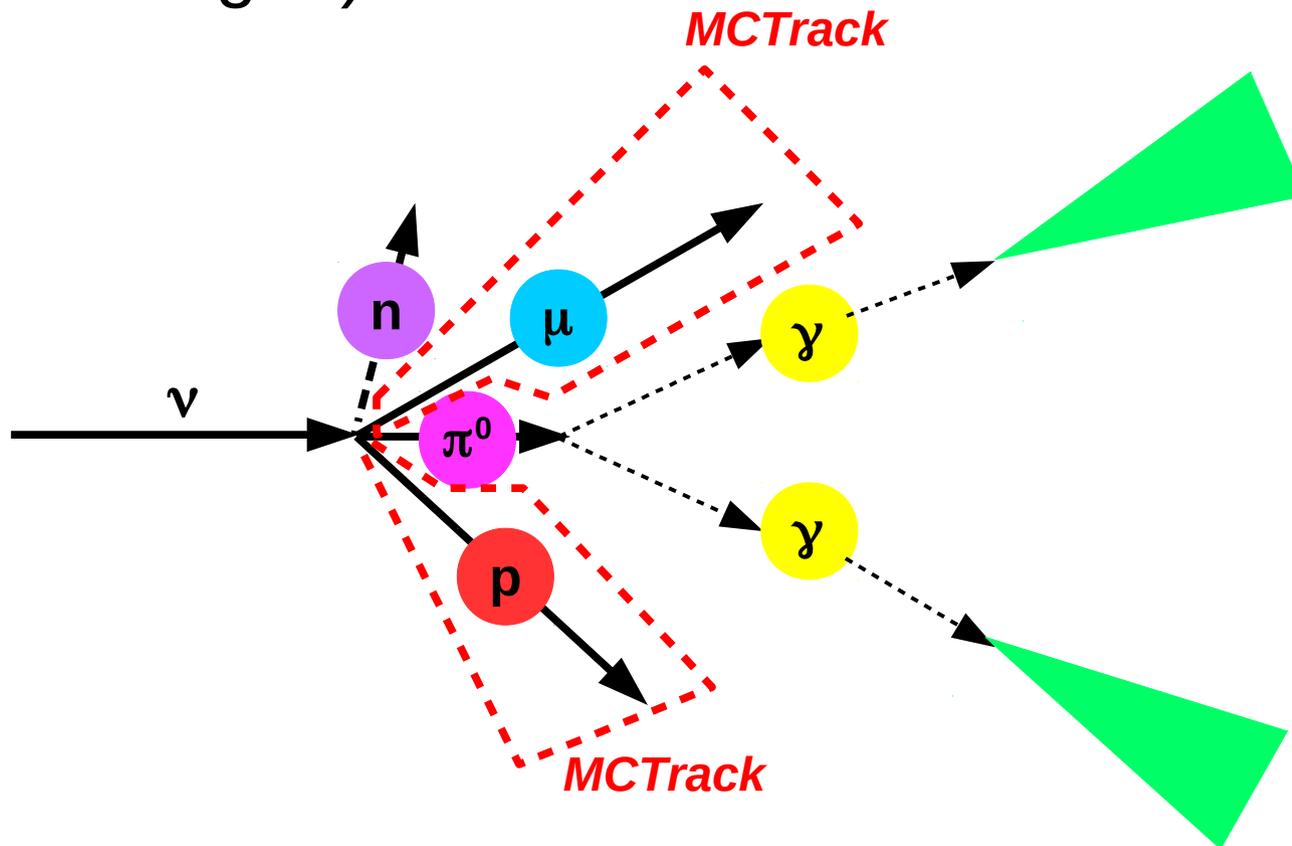
Near Term Strategy

- Take the Monte Carlo truth level objects so we can classify each event completely
- The use the LArSoft truth object MCTrack and MCShower to represent the 3d deposited charge information that would be seen by a pixel readout



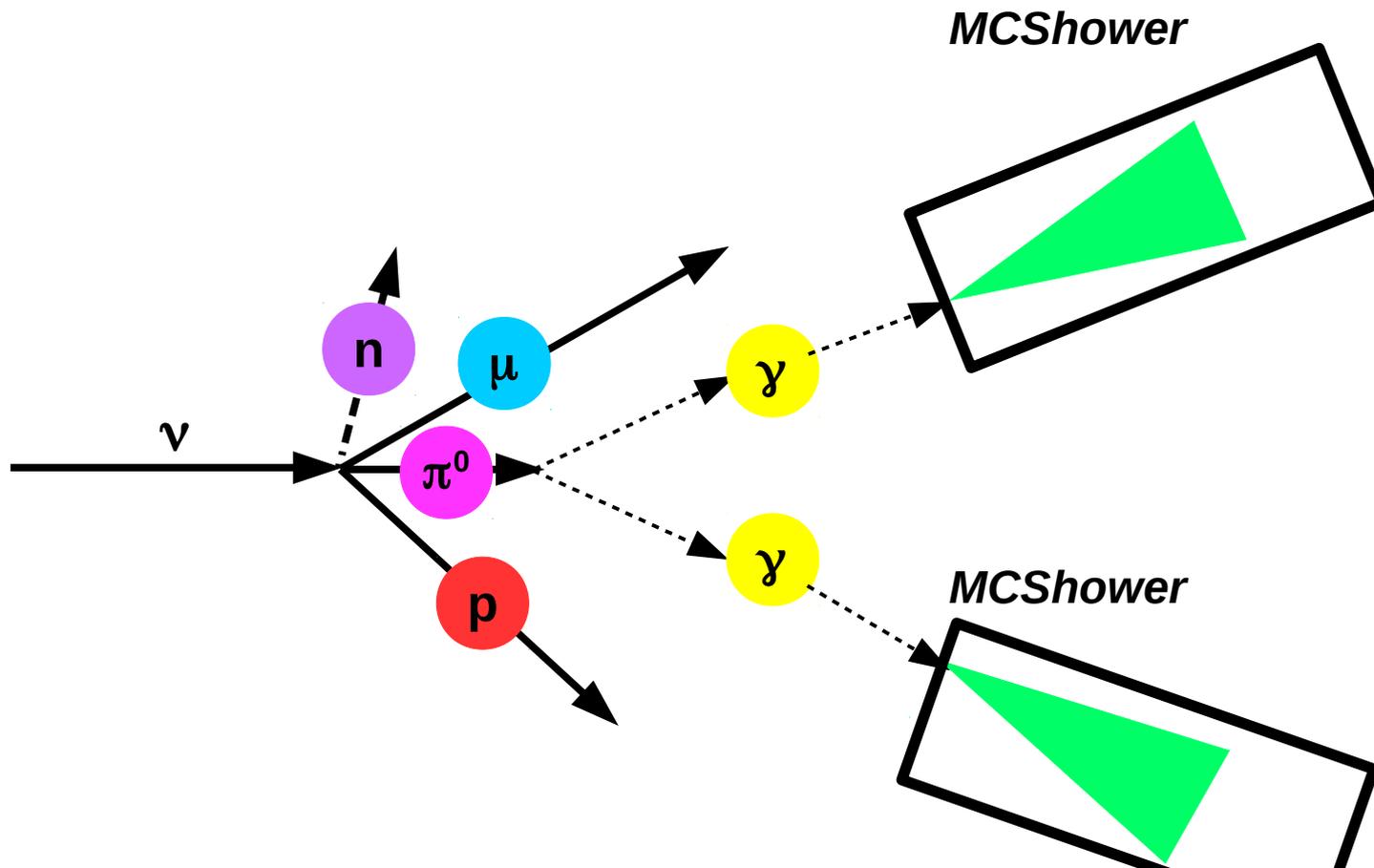
Near Term Strategy

- MCTrack represents the 3d deposited energy and momentum of an object that would create what you would think of as a “track”
 - e.g. Protons, muons, charged pions, kaons etc....
 - neutral particles aren't in the MCTrack (since they don't ionize the argon)



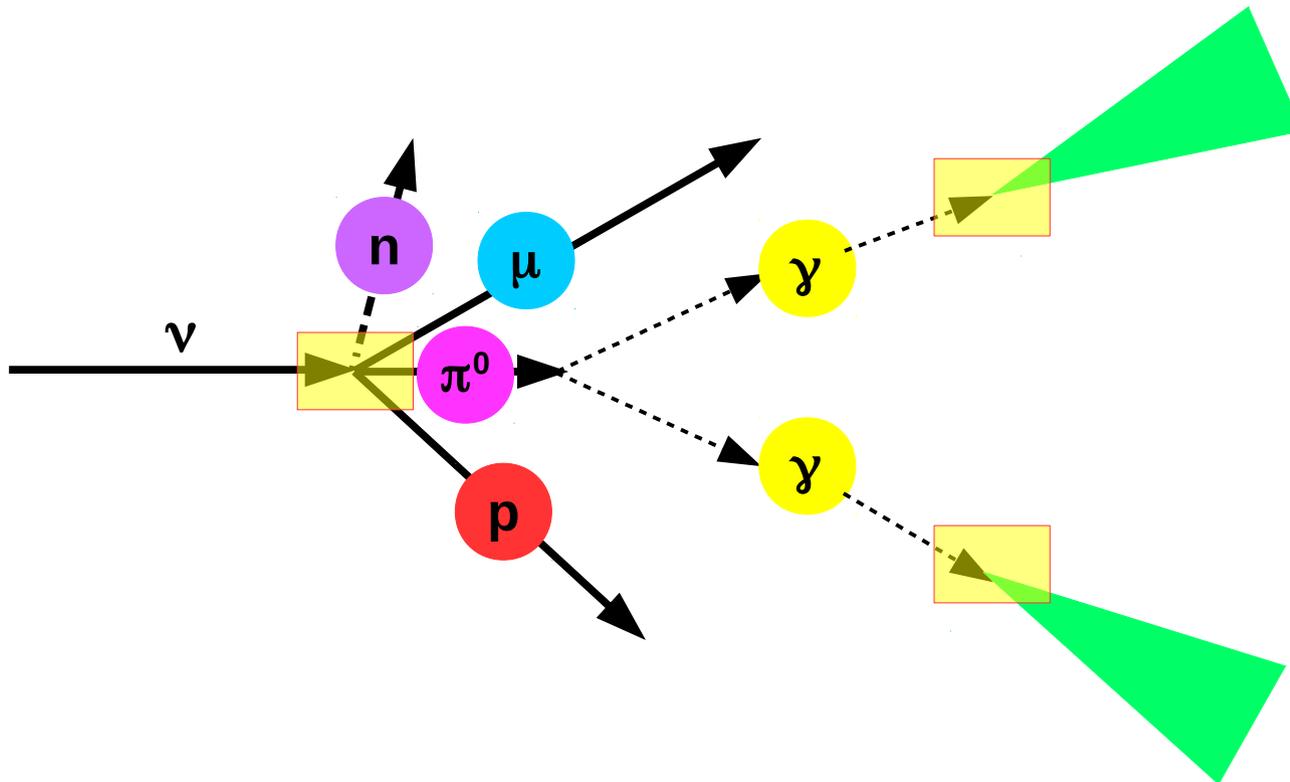
Near Term Strategy

- MCShower represents the 3d deposited energy and momentum of an object you would think of as a electromagnetic shower
 - e.g. photons and electrons



Near Term Strategy

- Since for all of these objects we have their true deposited energy position, momentum, and vertex position we can apply resolution smearing guided by the latest understanding from operating liquid argon experiments

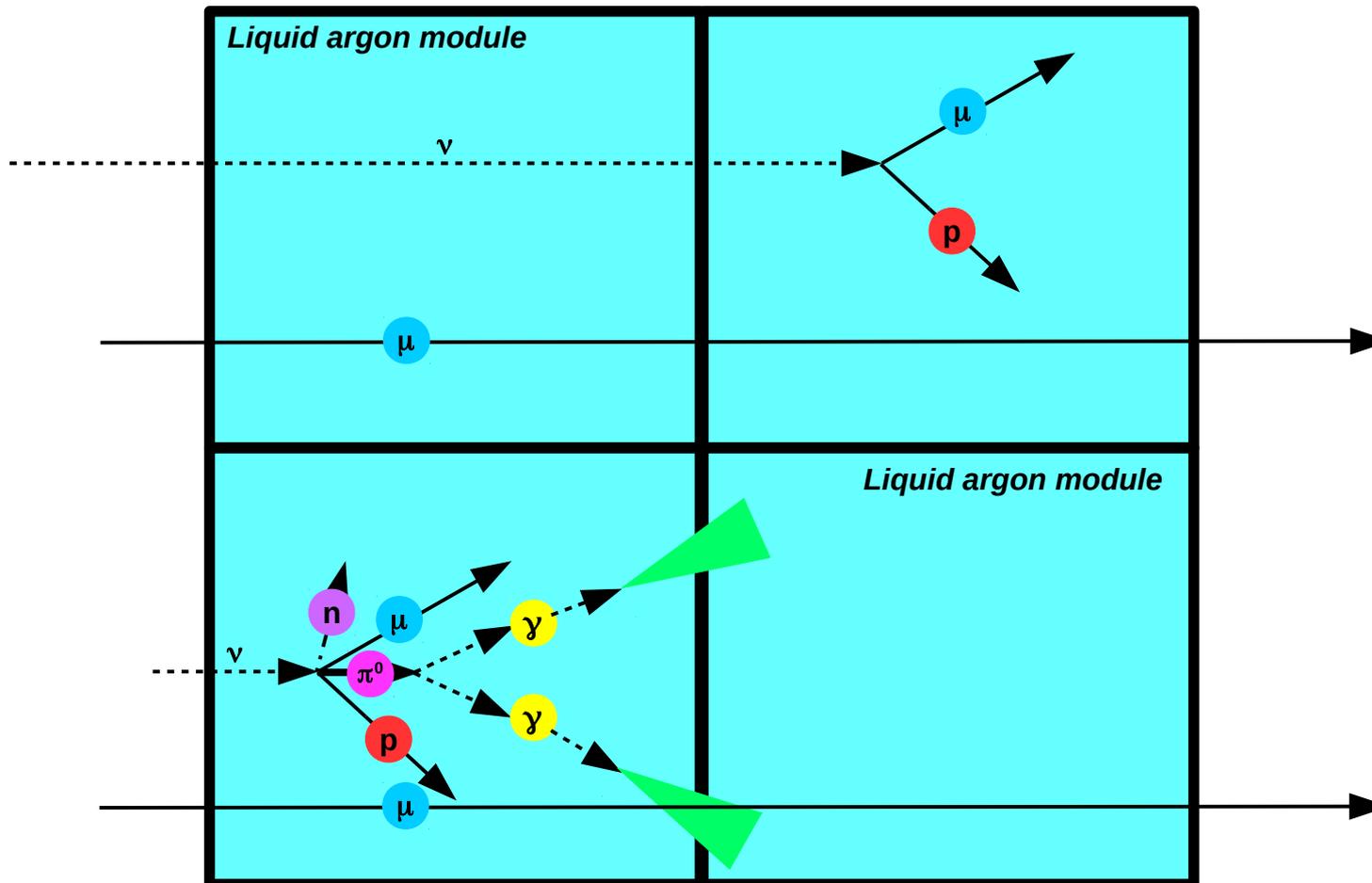


Near Term Strategy

- Additionally, we can use these tools to understand different effects

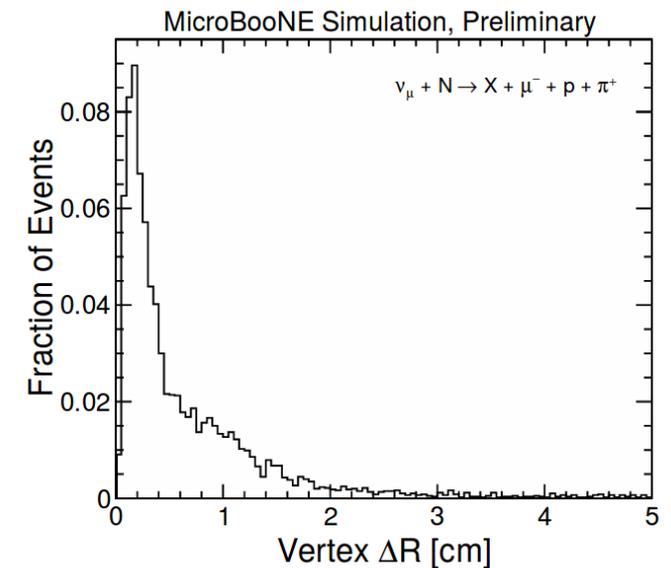
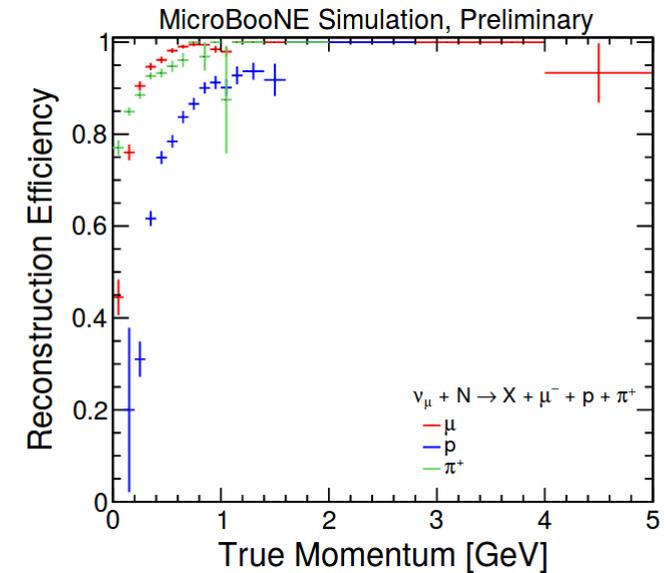
- Pile-up
- Containment
- Rock muons

Easy to draw the picture...a bit harder to get all these tools in place....but we are very close to having the first iteration of this type of study complete

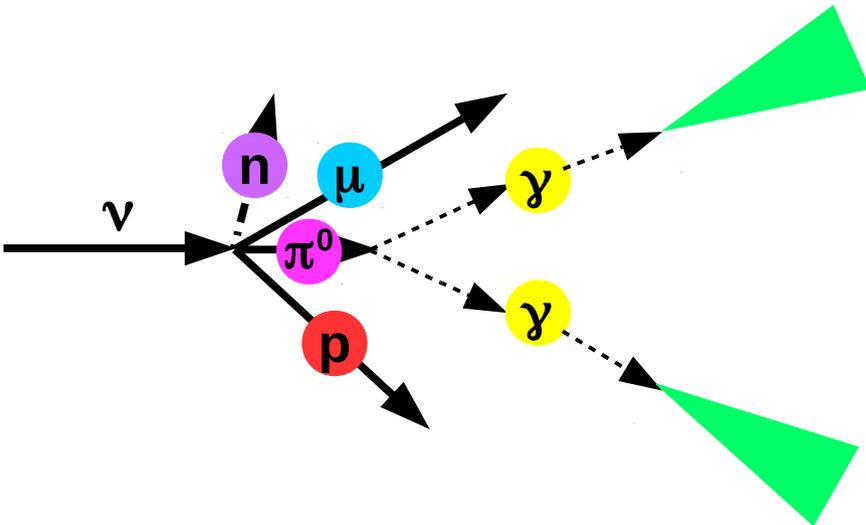


Near Term Strategy

- To begin with, we are applying a “smearing” to each vertex to fake the resolution
- We also smear out the start point of the MCTracks and MCShowers
- We then apply a PID efficiency to each MCTrack and MCShower
- Finally, we associate the “reconstructed” MCTrack and MCShowers to the vertex for neutrino interaction identification



See MicroBooNE public note:
“The Pandora multi-algorithm approach
to automated pattern recognition in LAr
TPC detectors “ 9
[MICROBOONE-NOTE-1015-PUB](#)





This work will wrap-up shortly in order to have input to the Near Detector Task force note document currently under preparation

However this won't represent what we think this technology can really do

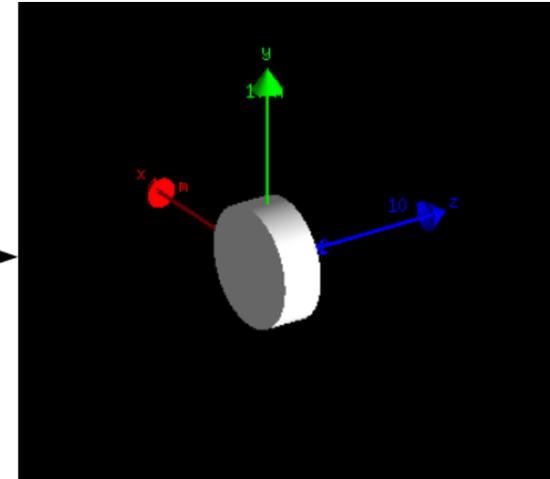
Medium Term Strategy

- **While this is a good place to start these tools aren't ideal if you are looking to do detector optimization studies and implement new tools (many of which won't work)**
- **For the work ongoing with the ArgonCube prototype we intend to use a Geant4 based simulation tool we've been developing**
 - Dark-Geant4 (DG4)
 - Initially named because we wanted a framework which we could do dark matter phenomenology studies using realistic Liquid Argon detector simulations

Medium Term Strategy (DG4)

```
World = { Material = "G4_AIR",  
          Volume_Type = "Box",  
          half_X = 20.0,  
          half_Y = 20.0,  
          half_Z = 20.0,  
          Inside = "None",  
          Position = {0, 0, 0} }
```

```
DetectorComponent_1 = { Material = "Liquid Argon",  
                        Volume_Type = "Cylinder",  
                        Inner_Radius = 0.0,  
                        Outer_Radius = 3.0,  
                        Half_Length = 1,  
                        Position = { 0, 0, 0 },  
                        Inside = "World" }
```

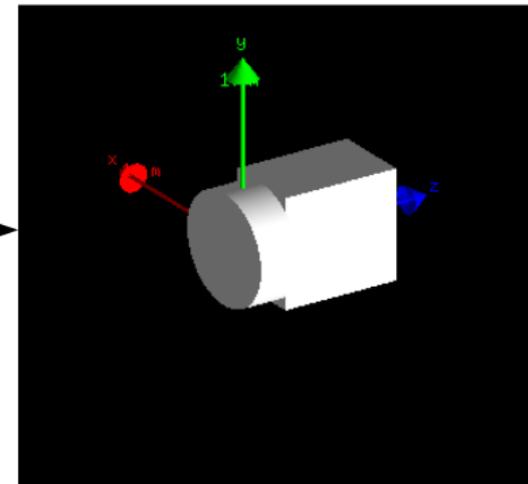


```
World = { Material = "G4_AIR",  
          Volume_Type = "Box",  
          half_X = 20.0,  
          half_Y = 20.0,  
          half_Z = 20.0,  
          Inside = "None",  
          Position = {0, 0, 0} }
```

```
DetectorComponent_1 = { Material = "Liquid Argon",  
                        Volume_Type = "Cylinder",  
                        Inner_Radius = 0.0,  
                        Outer_Radius = 3.0,  
                        Half_Length = 1,  
                        Position = { 0, 0, 0 },  
                        Inside = "World" }
```

```
DetectorComponent_2 = { Material = "Liquid Argon",  
                        Volume_Type = "Box",  
                        half_X = 2.0,  
                        half_Y = 3.0,  
                        half_Z = 3.0,  
                        Position = {0, 0, 4},  
                        Inside = "World" }
```

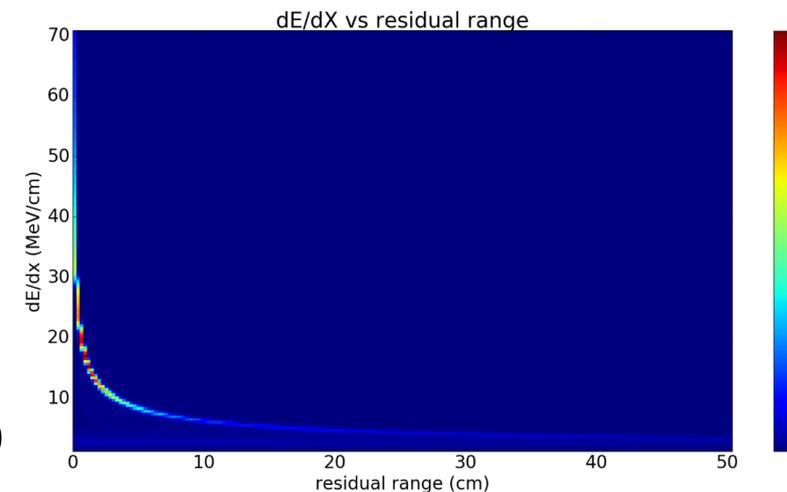
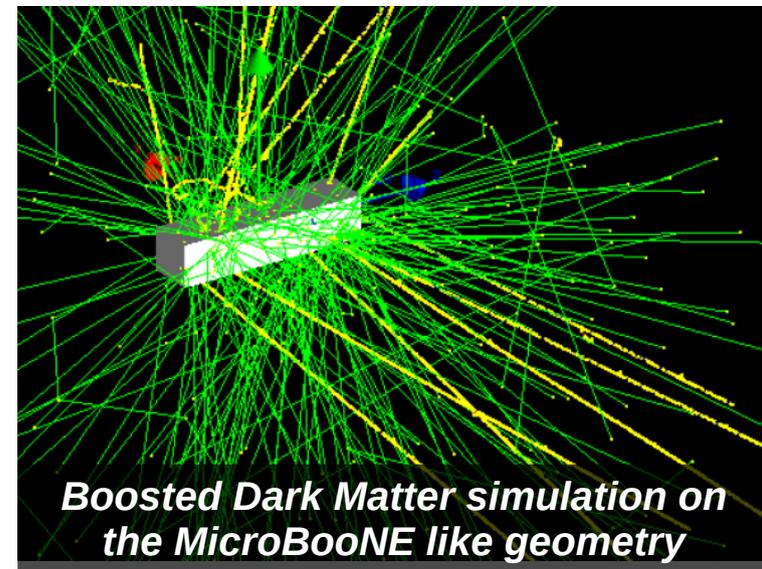
Additional
Component



- **DG4 allows the user to build your detector components (and visually render them) trivially using configuration scripts (Lua)**
 - So simple even faculty can do it!
- **This allows us to change things rapidly when trying to optimize detector configuration and materials**

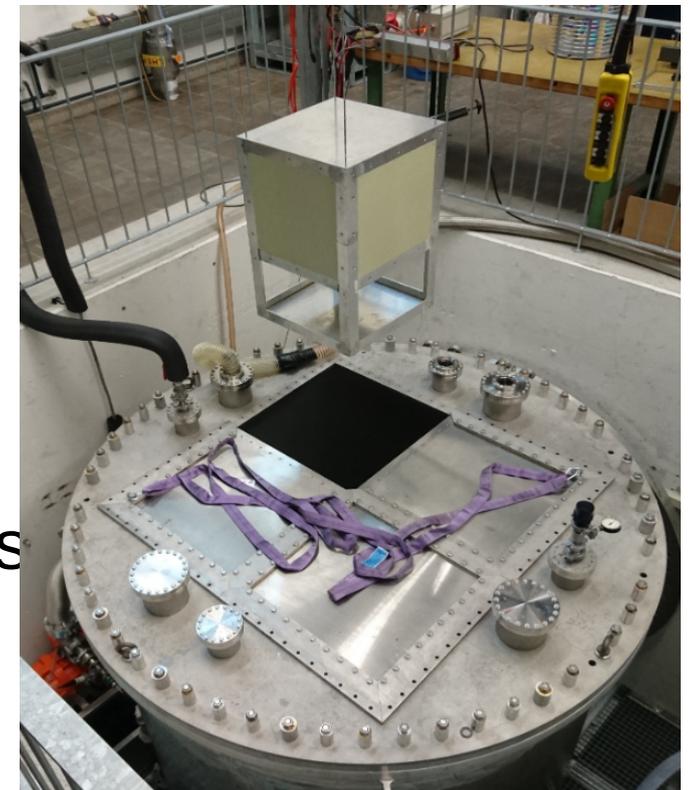
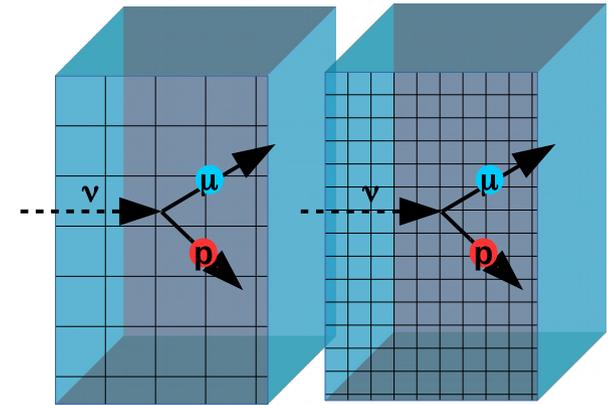
Medium Term Strategy (DG4)

- **DG4 can also take a variety of particle inputs**
 - Single particle Gun
 - Text file
 - HEPEvent format
 - CORSIKA Cosmic ray simulation
 - Working on supporting GENIE, NuWro, and other generator inputs
- **Also straightforward to explore the effect between different magnetic field layouts**
- **“Quick-and-dirty” analysis also very easy using python scripts to evaluate the physics**



Medium Term Strategy (DG4)

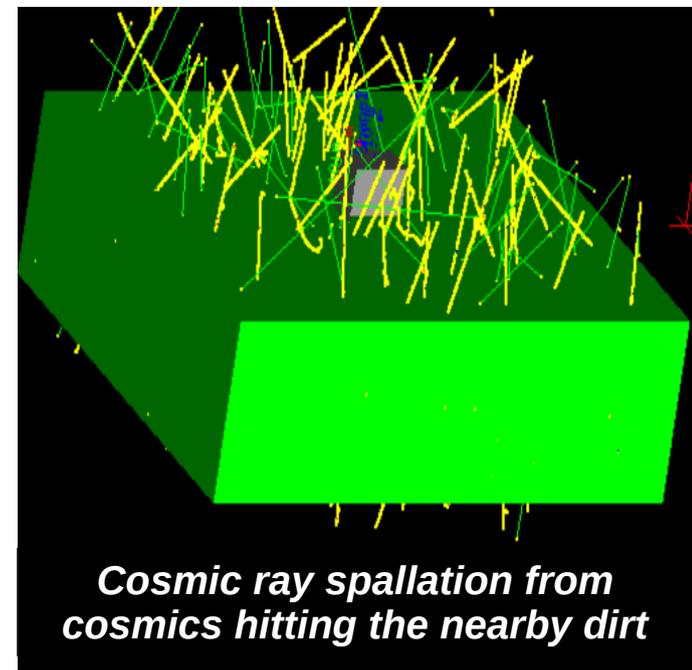
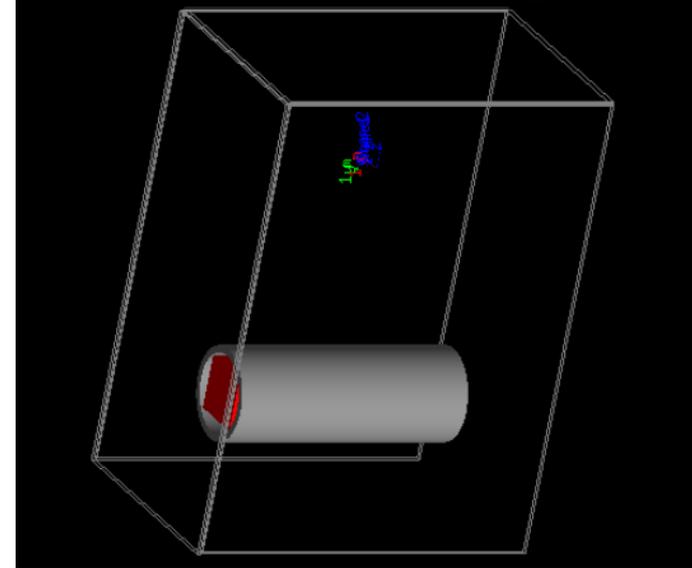
- This tool will allow us to pick different pixel pitches to “voxelize” our detector to study the expected resolution we should be able to achieve given different TPC sizes and pixel sizes
- Even better, we can quickly simulate the geometry and setup of the Bern prototypes and tune the simulation to match the data
 - This also allows us to understand what energy loss will occur between modules and how to optimize the material and detector layout



Medium Term Strategy (DG4)

- This tool will also allow us to do some relatively straightforward studies to understand the effect of what the surrounding material in the near detector hall and other detectors will do to the physics of the liquid argon option
 - We've done some preliminary studies of spallation from cosmic rays using a mock-up of MicroBooNE sitting inside a version of LarTF
 - When considering the hybrid option, this tool is well suited to explore what potential downstream detectors might expect to see coming from a liquid argon detector

MicroBooNE like detector inside a LArTF like building



Cosmic ray spallation from cosmics hitting the nearby dirt

- **While this tool will allow us to optimize a potential liquid argon near detector option it is NOT a replacement for all the sophistication LArSoft has to offer**
 - We won't have sophisticated electronics response
 - Complete recombination and diffusion models already in place in LArSoft (don't want to reinvent the wheel)
 - Latest and greatest reconstruction tools (for light and charge) already being developed in LArSoft
 - etc...etc...etc...

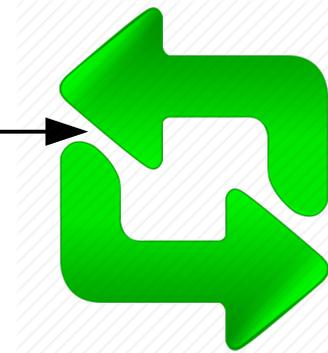
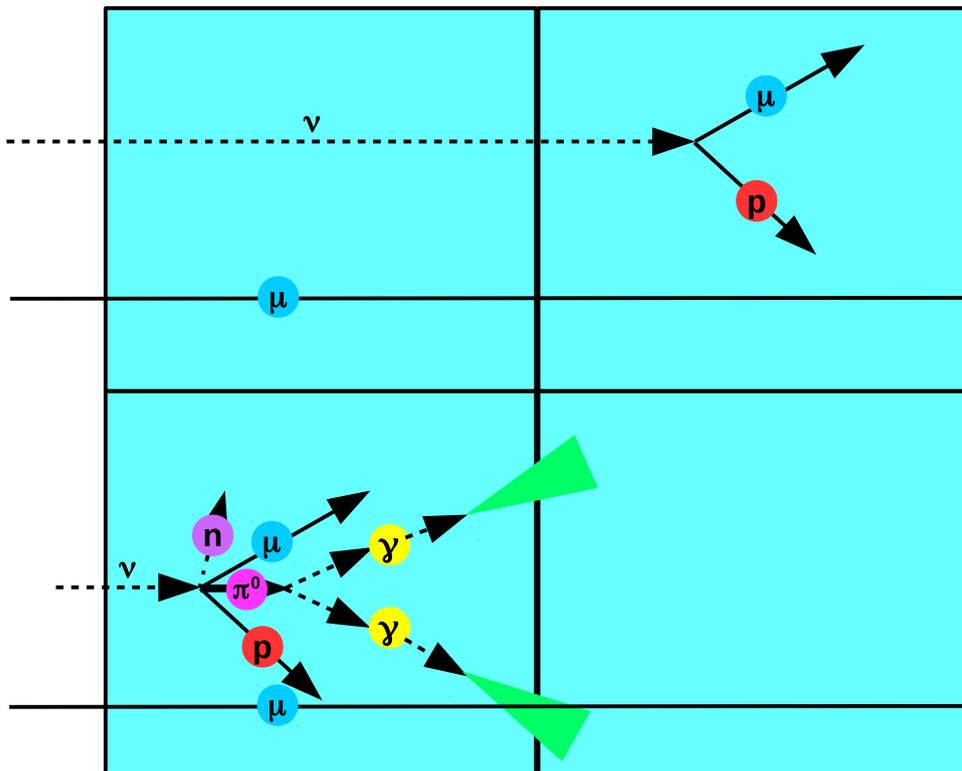
Longer Term Strategy

- **The strategy will be to take an optimized detector layout with a chosen pixel pitch and then incorporate that into LArSoft for further detector studies**



Longer Term Strategy

- This is where the tools we are developing now for the near detector task force can come back into play but with a more optimized detector layout
- We can also take what we've learned from the pixel approach and bring this as a detector component back into LArSoft
 - Could also be developed concurrently (provided people power is available)



DG4



Conclusions

- **We are working to rapidly complete the first study of a liquid argon near detector for the ND-task force using the best tools we have on hand and the current best understanding of reconstruction and PID efficiencies**
 - Hopefully complete this very shortly
- **To better optimize the detector layout and explore the nuances of the 3d pixel readout we will utilize a lightweight Geant4 simulation package we've been developing for LAr phenomenology studies**
 - Work closely with the Bern's ArgonCube tests to iterate on various detector configurations and tune the simulation to data collected from prototypes
 - Also allow for the exploration of hybrid solutions with various detectors in the same near detector hall
- **Finally, work with an optimized layout to incorporate this detector back into the LArSoft framework for a more complete physics study**